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Growth Response In

Allegheny Hardwood Forests

After Diameter-Limit Pulpwood Cuttings

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THE HIGH COST OF HARVESTING SMALL TREES

VALUABLE SECOND-GROWTH Allegheny hardwood-hemlock forests are found in the High Plateau section of the northern Allegheny Plateau. These forests are valuable as a habitat for wildlife, for regulating streamflow and protecting against erosion, for recreation, and as a source of timber products for industry.

Many of these second-growth stands contain a large proportion of black cherry--one of the most valuable lumber species--and associated hardwoods such as white ash, sugar maple and red maple, American beech, yellow birch, and black birch. The principal conifer associate is eastern hemlock.

These forests are not static; they are growing and changing in species composition, operable volume, and stand

quality under the impact of many biologic, climatic, and economic factors. Whether a given forest stand changes for better or for worse depends in large part on the policy of land management employed by the landowner. Is the land to be used primarily as a commercial forest from which timber products are cut? Or is it to be a noncommercial park or a reservation for game production? Is the owner interested only in one use or product or in the multiple uses of his forest land?

Lands of the Armstrong Forest Company (an affiliate of the New York and Pennsylvania Pulp and Paper Company) in northwestern Pennsylvania have been under fire protection for 30 or 40 years. Forest management for pulpwood production was begun following the severe glaze storm of March 1936. This company has been a pioneer in developing practical methods of forest management which could be applied to their holdings of some 68,000 acres of Allegheny hardwoods (1, 2, 3).[1]

In 1940 a study of the cost of producing peeled pulpwood from trees of various diameter classes was made on lands of the Armstrong Forest Company in cooperation with the Forest Service. The results of this test have been reported by Ostrom (8) and Hough (5). Articles based on this study were prepared by Swingler (10) and Lentz (7).

Briefly, the study showed that the average pulpwood cutter could produce almost twice as much solid pulpwood per day from trees 11 inches d.b.h. and larger as he could from trees 5 to 8 inches d.b.h. Workers were obliged to cut almost six times as many 5- to 8-inch trees as large trees to make a "cord" of 52-inch pulpwood. Weekly piecework earnings were $8.32 less when cutting small trees as compared to the medium (8.0 to 10.9 inch d.b.h.) or large (11.0 to 17.0 inch d.b.h.) trees. Earnings were equal for the last two groups, but in terms of labor cost per 100 cubic feet of solid wood, the least cost was incurred in converting the large trees into pulpwood. In other words, the ricks of small wood contained 18 percent less cubic volume than those of greater average size per stick from larger trees.

It is well known by the foresters, wood jobbers, and woodcutters on the Armstrong Forest Company operations that size has a definite and profound influence on the productiv-

[1] Underlined numbers in parentheses refer to Literature Cited, page 17.

ity of woods labor and the volume of solid wood material per cord. The number of trees per cord, man-hours of conversion time, and labor cost per cord or cunit[2] all increase as the size of trees cut in second-growth stands decreases.

Earnings of the woodcutter drop off sharply the greater the proportion of trees below 8 inches d.b.h. are handled. Costs to the company increase, because of the reduction in solid content of cords from small-diameter sticks.

Other recent studies of cordwood cutting bear out the same general conclusion. Conversion time for mine props in the Anthracite Region of Pennsylvania increases markedly for trees below 8 inches (4). A study of chemical-wood conversion costs in Potter County, Pennsylvania, gave similar results (9). Jensen (6) found that tree size was a major factor affecting per-cord costs of pulpwood conversion in second-growth spruce-fir forests of the upper Connecticut River. Wood from 5-inch trees cost almost twice as much to deliver as that from 13-inch trees. Cordwood could be produced with the minimum cost from 10- to 12-inch trees.

Such results provide definite reasons for persuading contractors and woodcutters cutting pulpwood to leave the trees below 8 inches d.b.h. for future growth. After this study the Armstrong Forest Company adopted the policy of operating on this 8-inch diameter limit in cutting.

But a question remained to be answered: How much growth in pulpwood volume can be expected in the stands cut to different diameter limits? A follow-up study of stand development during the 10 years after cutting provided some answers to this question.

A FOLLOW-UP STUDY OF GROWTH

The same plots used in the diameter-limit study of harvesting costs were used in a follow-up study of the growth on areas that had been cut to three different diameter limits. The objective of the study was to determine the net growth in volume per acre, in terms of cubic feet and 52-inch peeled pulpwood units.

[2]A cunit is a theoretical unit that contains 100 cubic feet of solid wood.

The study area is located on a plateau top 1,900 feet above sea-level in the Wolf Run Experimental Forest of the Armstrong Forest Company. Before cutting, the 43-year-old second-growth stand averaged 21 units of 52-inch peeled pulpwood (2,100 cubic feet gross volume) per acre in trees 5 inches d.b.h. and larger. The site is good, and about half of the volume was in trees 11 inches to 17 inches d.b.h. The species composition, based on cubic-foot volume, was 68 percent black cherry, 11 percent sugar maple, 11 percent beech, 5 percent red maple, and 5 percent birches, white ash, and hemlock.

A re-tally was made of all living trees 5 inches d.b.h. and larger on the plots (table 1) at the end of the

Table 1.--Description of plots used in study of growth after diameter-limit cuttings, 1940-49

Diameter limit used in cutting	Plot dimensions	Area	Plots used	Total area
	Chains	Acres	No.	Acres
5.0 inches d.b.h.	2 x 2½	0.5	6	3.0
8.0 inches d.b.h.	2 x 3½	.7	6	4.2
11.0 inches d.b.h.	2½ x 4*	1.0	6	6.0
All treatments	--	--	18	13.2

*Two of the 11-inch diameter-limit plots were 3.16 chains square.

1945 and 1949 growing seasons, for comparison with the stand tally made immediately after cutting in the spring of 1940. Since no trees were tagged individually, detailed data on mortality and growth by species and diameters are not available. The total growth of all species and all trees surviving on each plot is thus net growth (less mortality). The same even-inch d.b.h. classes used in the original study were naturally used in the re-tallies.

Basal area and volume data compiled for each plot were used to determine the net growth per acre for each treatment. Local cubic-foot volume tables and cordwood converting factors were available from the previous cost study. All six plots of each diameter limit were used to get average per-acre values.

Estimates of the time needed to replace the average amounts cut in 1940 were made for each treatment as a rough guide to the length of cutting cycle associated with the various degrees of cutting. The volume of operable pulpwood in trees 8 inches and larger which has been produced in 10-years' growth was computed for each treatment.

TOTAL GROWTH AFTER TREATMENT

The average total 10-year-growth per acre for each treatment--in square feet of basal area, cubic-foot volume, and peeled pulpwood volume of 52-inch units and 100-cubic-foot solid cunits--is given in table 2. These figures are based on stand tallies of all living trees 5 inches d.b.h. and larger left on the respective plots in 1940 and those present 10 years after cutting. The appearance of representative plots of each treatment 5 and 10 years after pulpwood cutting is illustrated in figures 1, 2, and 3.

To judge from the results, there is very little difference in the total growth response to the 8- and 11-inch cuttings. The relatively poor showing from the 5-inch diameter cutting is to be expected. Since all trees 5 inches d.b.h. and larger (with the exception of a few hemlock) were cut in 1940, the bulk of the 10-year growth came from trees just below the minimum size that grew into measurable size. In other words, ingrowth.

To show these results more vividly, all figures except cunits have been graphed (fig. 4). Stand response,

Table 2.--Basal area and volume per acre 10 years after diameter-limit cuttings

Diameter limit used in cutting	Growth in basal area		Growth in volume[1]					
	10 years	Annual	10 years	Annual	10 years[2]	Annual	10 years[3]	Annual
	Square feet	Square feet	Cubic feet	Cubic feet	52" cords	52" cords	Cunits	Cunits
5.0 inches d.b.h.	27.4	2.7	459.9	46	5.1	0.51	4.7	0.47
8.0 inches d.b.h.	32.3	3.2	629.0	63	6.5	.65	6.2	.62
11.0 inches d.b.h.	32.1	3.2	689.4	69	6.6	.66	6.5	.65

[1]All living trees 5.0 inches d.b.h. and larger were included regardless of whether they could be converted to pulpwood profitably. Volumes are for peeled wood, based on local volume table.

[2]The factors used for converting cubic feet to 52-inch cord volumes are as follows: For trees 5.0 to 7.9 inches d.b.h.--89.0 cubic feet per cord. For trees 8.0 to 10.9 inches d.b.h.--97.5 cubic feet per cord. For trees 11.0 inches d.b.h. and larger--104.8 cubic feet per cord.

[3]A cunit is a theoretical unit that contains 100 cubic feet of solid wood. These figures depend on the stand-size class distribution and on the converting factors shown above.

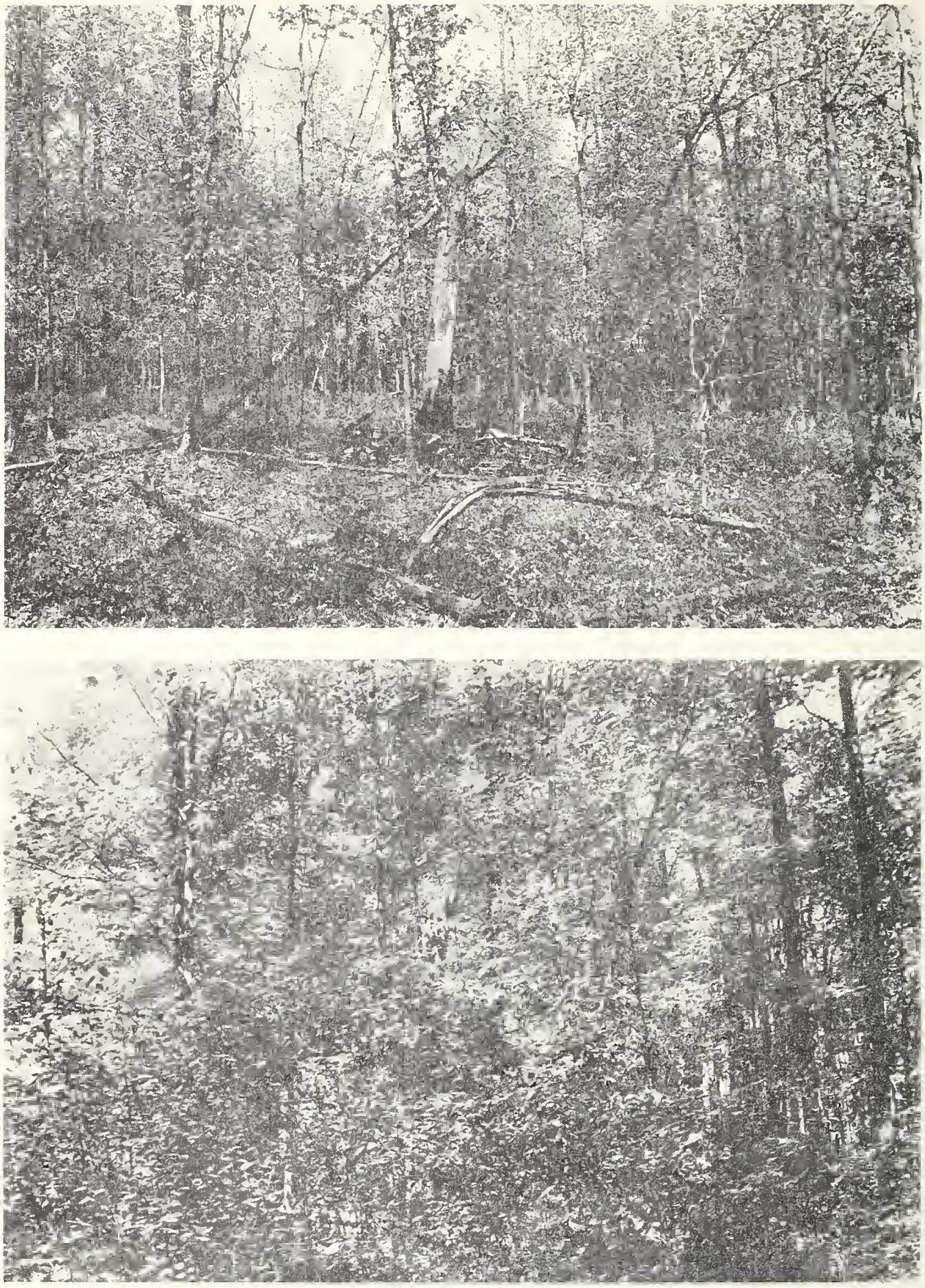

Figure 1.--A plot cut to a 5-inch diameter limit.

Top: Five years after cutting. Note the sparse residual stand and new reproduction.

Bottom: Ten years after cutting. Note the greater height and thicker stocking of seedling black cherry and other reproduction.

Figure 2.--A plot cut to an 8-inch diameter limit.

Top: Five years after cutting. Reproduction of black cherry and other species is found in the larger openings.

Bottom: Ten years after cutting. Increased height growth of the reproduction is apparent.

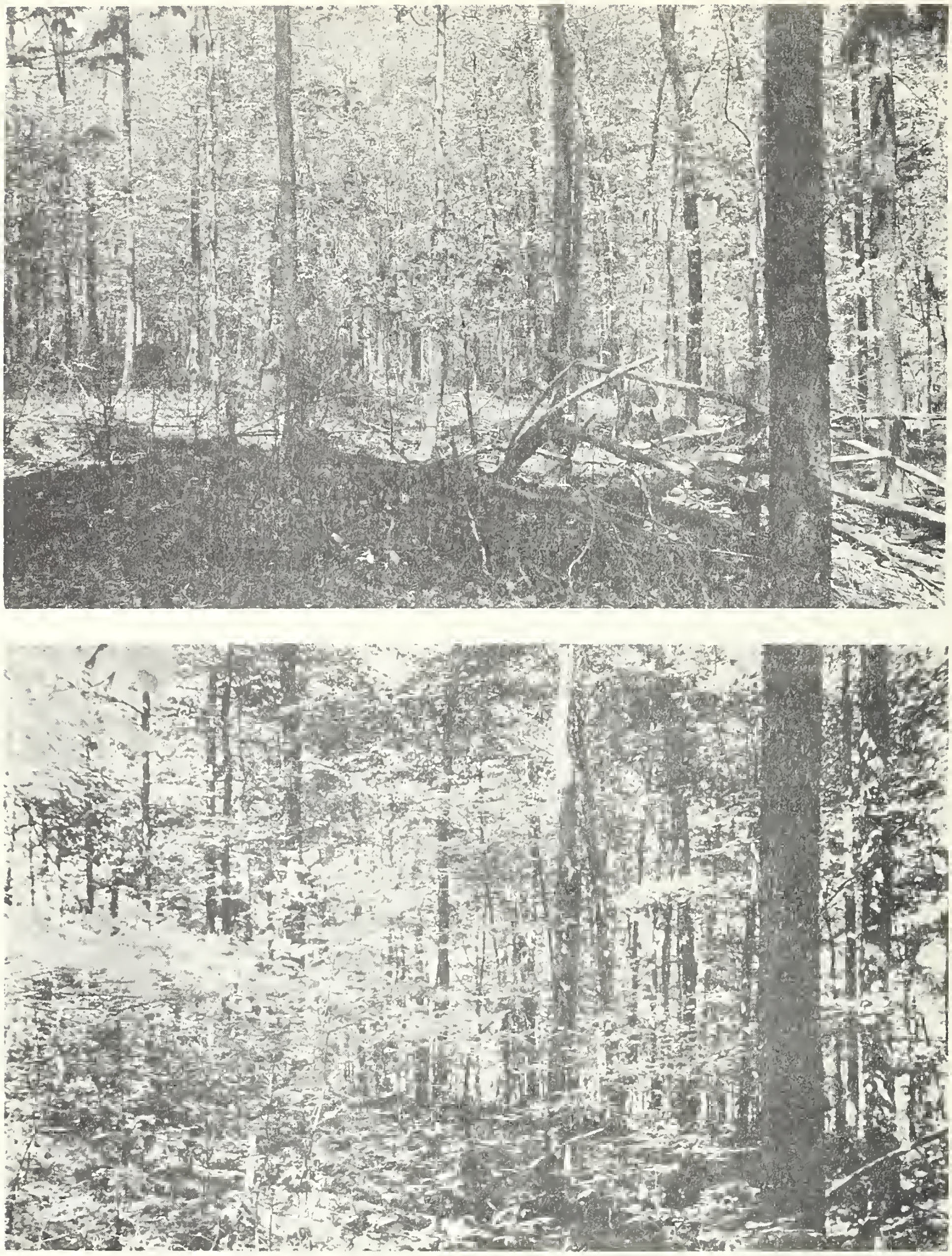

Figure 3.--A plot cut to an 11-inch diameter limit.

Top: Five years after cutting. Note the slash left from the 1940 pulpwood cutting. A growth of tolerant reproduction has come in under the fairly dense residual stand.

Bottom: Ten years after cutting. The tolerant sugar maple and beech are growing well in partial openings. The residual stand is growing well.

whether measured in basal area or in cubic feet or pulpwood volume, is consistent for each treatment. Invariably those areas cut to a 5-inch limit, on which there was least growing stock left after cutting, made the poorest recovery both in the first and second 5-year periods. An attempt has been made to estimate the length of time required to replace the entire amounts cut in 1940 for each treatment. The results for both basal area and volume replacement time are shown in figure 4 and table 3.

Table 3.--Time required to replace material cut

Diameter limit used in cutting	Estimated time required to replace material cut		
	Basal area	Volume (cubic feet)	Volume (cords)
	Years	Years	Years
5.0 inches d.b.h.	33	34	34
8.0 inches d.b.h.	25	26	25
11.0 inches d.b.h.	15	16	16

Fluctuations in the rate of current annual increment between the first and second 5-year growth periods have been noted. This indicates the difficulties of estimating future growth in a managed stand--that is, after cutting--from a short-term record. It is of interest that the heavier 5- and 8-inch cuttings, which made ample room for crown expansion and ingrowth, actually speeded up current annual increment during the second 5-year period as compared to the first period; while the rate of increase for the 11-inch cutting slowed down during the second period (fig. 5).

It is true that initial mortality after heavy cutting commonly takes place during the first 5-year period, and that growth of suppressed trees picks up once they have recovered from the shock of a sudden opening up of the canopy. Ingrowth also continues and may accelerate during the second 5-year period after a very heavy or heavy cutting such as the 5- and 8-inch diameter-limit cuttings. On the other hand, for the 11-inch cutting the slowing down of growth in the second 5-year period--as compared to the first--may well be due to increasing competition following rapid crown closure and build-up of the growing stock. This treatment was essentially a thinning from above and left a dense pole stand of sugar maple and other species with little room for crown expansion.

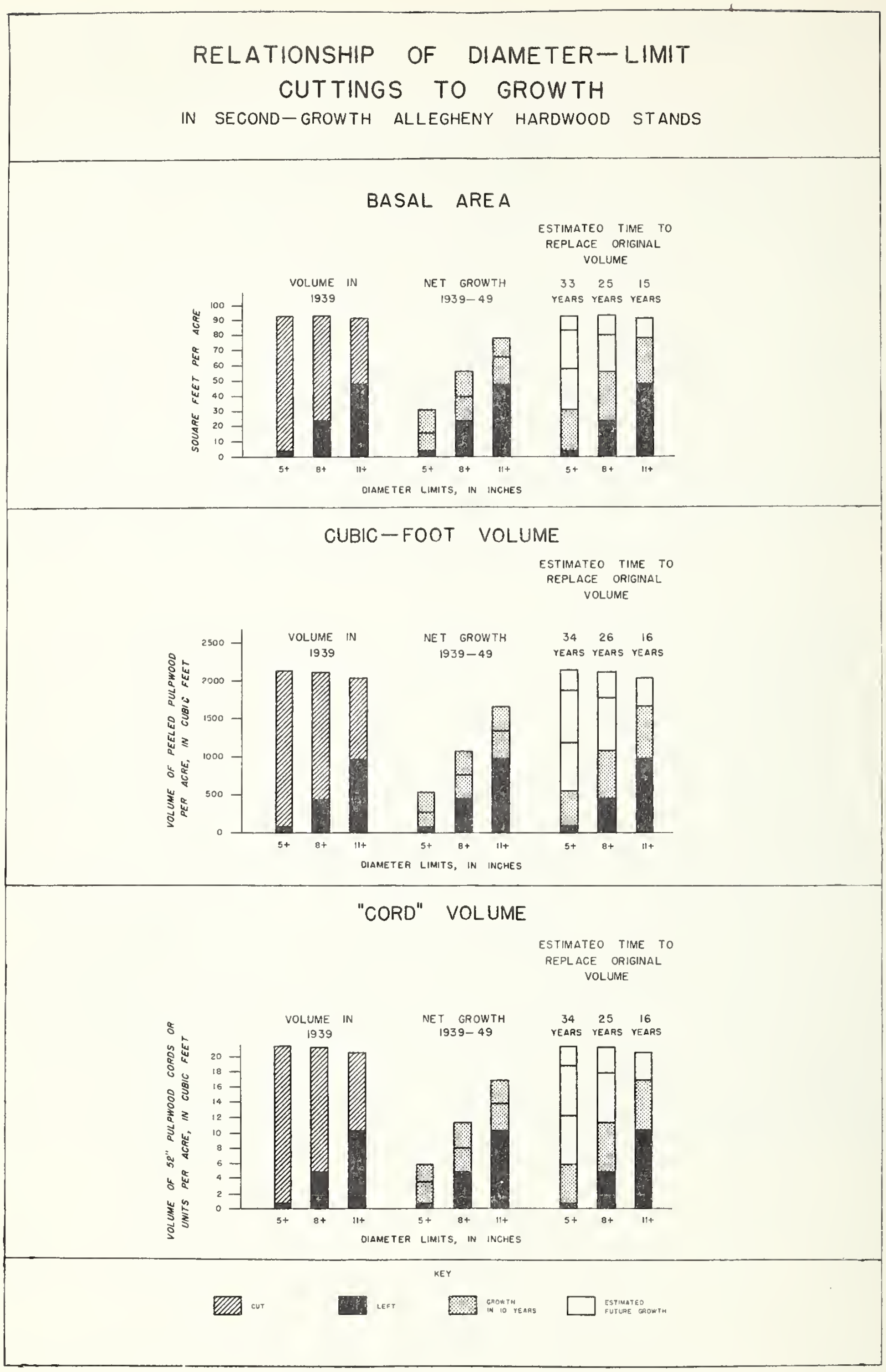

Figure 4.--The relationships of growth to three different kinds of diameter-limit pulpwood cuttings in second-growth Allegheny hardwood stands.

GROWTH AVAILABLE FOR PULPWOOD AT TIME OF NEXT CUT

Up to this point all data on basal area and volume have included all living trees down to the minimum size of 5 inches tallied on the pulpwood cutting plots.

Since the policy of the Armstrong Forest Company has been to operate pulpwood on their lands on an 8-inch d.b.h. minimum tree size for cutting, we should re-examine the 10-year growth figures on that basis. The fact is that part of the volume known to be added by growth of the entire stand 5 inches d.b.h. and larger is actually not available. How much of this growth is made up of trees between 5.0 and 7.9 inches in diameter that is locked up as potential pulpwood and is not operable at maximum efficiency by the woodcutter and company?

Figure 6 and table 4 show a comparison of the wood volume in cords and cunits per acre grown in a 10-year period by all trees 5 inches d.b.h. and larger and by those 8 inches d.b.h. and larger. As would be expected, the plots cut to a 5-inch limit in 1940 had most of their regrowth in the 5.0- to 7.9-inch trees and thus the lowest amount of operable (8 inches +) volume added during the 1940-1949 period. Even on the 11-inch cuttings the tying up of about 1.5 cunits in potential pulpwood below the 8-inch diameter limit is a factor of considerable importance.

This situation was encountered by the author and A. L. Bennett of the Armstrong Forest Company in 1950. At that time we had data on total 10-year volume growth on trees 5 inches +. We tried to selectively remove this volume from four of the plots cut to 11 inches d.b.h.--without dipping below the 8-inch limit. We couldn't do it. Much of the volume simply was not operable. To remove it we would have had to dip below the 8-inch limit and cut heavily into the largest and fastest growing trees. The alternative was to take a lighter cut by removing only the 10-year growth put on by trees 8 inches and larger.

SUMMARY & CONCLUSIONS

The growing stock left in second-growth stands cut to a 5-inch diameter limit was practically zero, with the exception of a few holdover hemlock trees that could not be used for pulpwood. Growth in total basal area or volume per

Table 4.--Comparative basal area, volumes, and value of pulpwood produced by growth in 10 years after pulpwood cutting to different diameter limits

Item *	5-inch diameter limit			8-inch diameter limit			11-inch diameter limit		
	In 1940	In 1949	10-year growth	In 1940	In 1949	10-year growth	In 1940	In 1949	10-year growth
Basal area.............square feet..	3.5	30.9	27.4	23.6	55.9	32.3	47.8	79.9	32.1
Total volume...........cubic feet..	72.5	532.4	459.9	439.1	1068.1	629.0	962.2	1651.6	689.4
...52-inch pulpwood units..	.7	5.8	5.1	4.8	11.3	6.5	10.2	16.8	6.6
...cunits..	.6	5.3	4.7	4.6	10.8	6.2	10.0	16.5	6.5
Operable volume............cunits..	.2	1.4	1.2	2.5	6.0	3.5	7.7	12.7	5.0
Value of operable volume...dollars..	.40	2.80	2.40	5.00	12.00	7.00	15.40	25.40	10.00

*Data for basal areas and total volumes are based on living trees 5.0 inches d.b.h. and larger present on the plots at time of measurement, converted to a per-acre basis. Operable volumes and values include only that portion of the stand 8.0 inches d.b.h. and larger. Potential pulpwood in growing stock 5.0 to 7.9 inches d.b.h. has been excluded to conform to company policy of minimum tree size for cutting.

acre was least during the 10-year period 1940-49 on those plots cut to a 5-inch limit. Cutting to an 8-inch or 11-inch diameter limit left progressively more growing stock and resulted in more rapid recovery during this same period. The length of time required to replace the basal area or volume cut in 1940 has been estimated at approximately 34, 25, and 15 years, for the 5-, 8-, and 11-inch cuttings respectively.

Total volume production is less useful as a guide to the relative worth of these cutting limits than is the amount of operable volume added by growth in the first decade. By operable volume is meant that in trees 8 inches d.b.h. and larger which may be cut or operated at a profit.

In cunits of 100 cubic feet of solid wood as a uniform basis of measure, the 11-inch cutting ranks first in operable volume produced in the first decade. The 8-inch cutting is much better than the 5-inch cutting in the proportion of operable volume to total volume added by growth. In terms of operable stumpage at $2 per cunit, the 11-inch cutting method produced growth at the rate of $1 per acre per year, the 8-inch treatment at 70 cents, the 5-inch treatment at 24 cents.

Forest lands in the Allegheny Plateau region from which all merchantable pulpwood has been removed at one cutting down to a 5-inch diameter will regrow only 1.2 cunits per acre of operable pulpwood (on trees 8 inches d.b.h. and larger) during the succeeding decade. This volume, which may be operated at a profit, is insufficient to attract a pulpwood contractor for the purpose of making a recut at this time. Costs of operation, especially with the greater investment in power saws and the present higher wage scale for woods labor, are too high to make a profit on those trees under 8 inches d.b.h.

The growth on such land is thus locked up in two ways: (1) in tree sizes too small to be operated at a profit; and (2) in volumes per acre below the minimum number of cords or cunits possible to operate at a profit. This means the cutting cycle must be lengthened considerably beyond a 10-year period to build up the operable volume, thus adding to the cost of wood production. Even the 3.5 "cords" (equal to 3.5 cunits) of pulpwood added by 10-year growth on the 8-inch cutting is barely enough to attract an operator.

Every forester has been taught to abhor waste and to urge the woodcutter to utilize the felled tree well into the top. In the Allegheny Plateau region the standards for

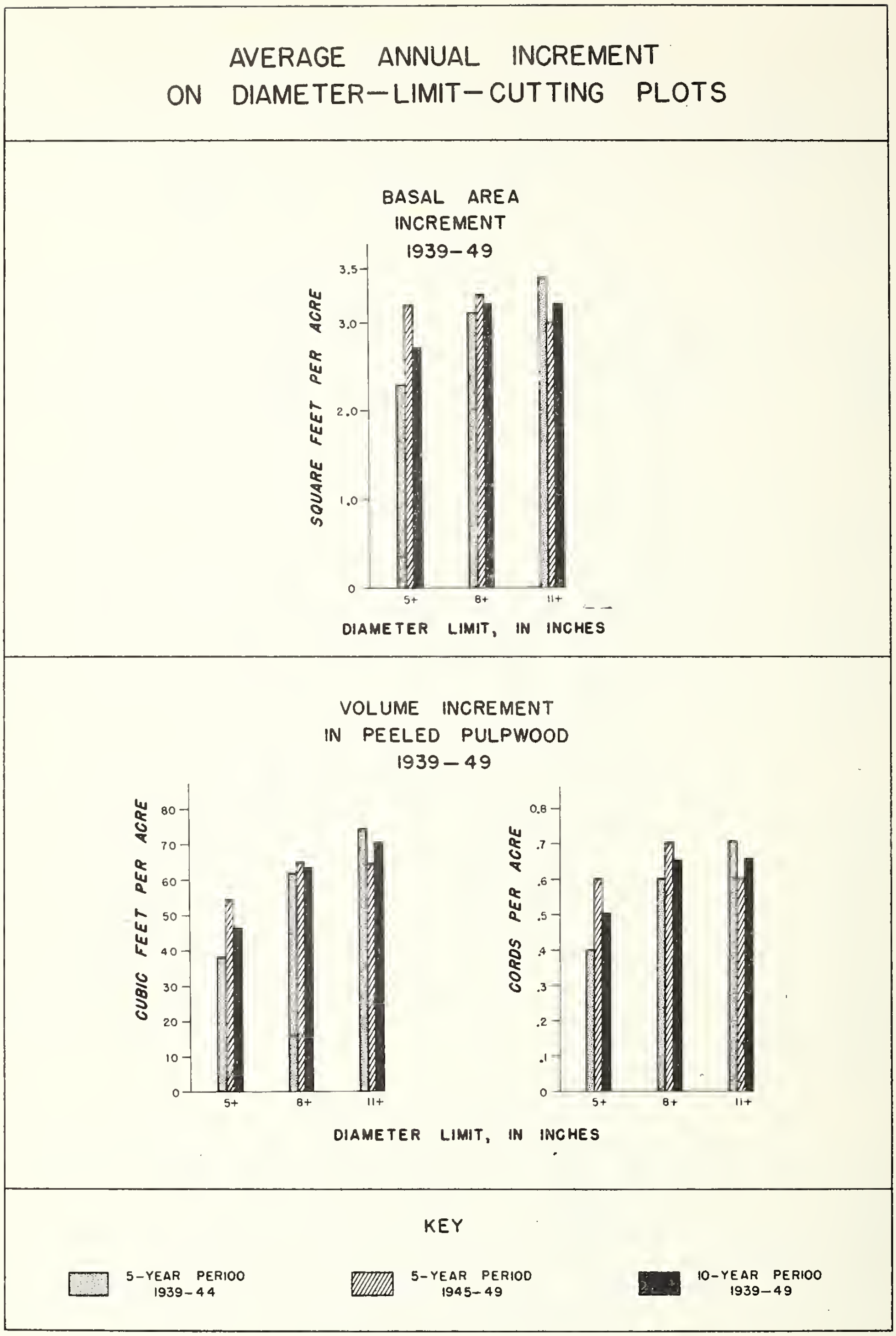

Figure 5.--Comparison of increment after three kinds of diameter-limit cuttings. Note how the increment rate slowed down during the second 5-year period on plots where an 11-inch diameter limit was used.

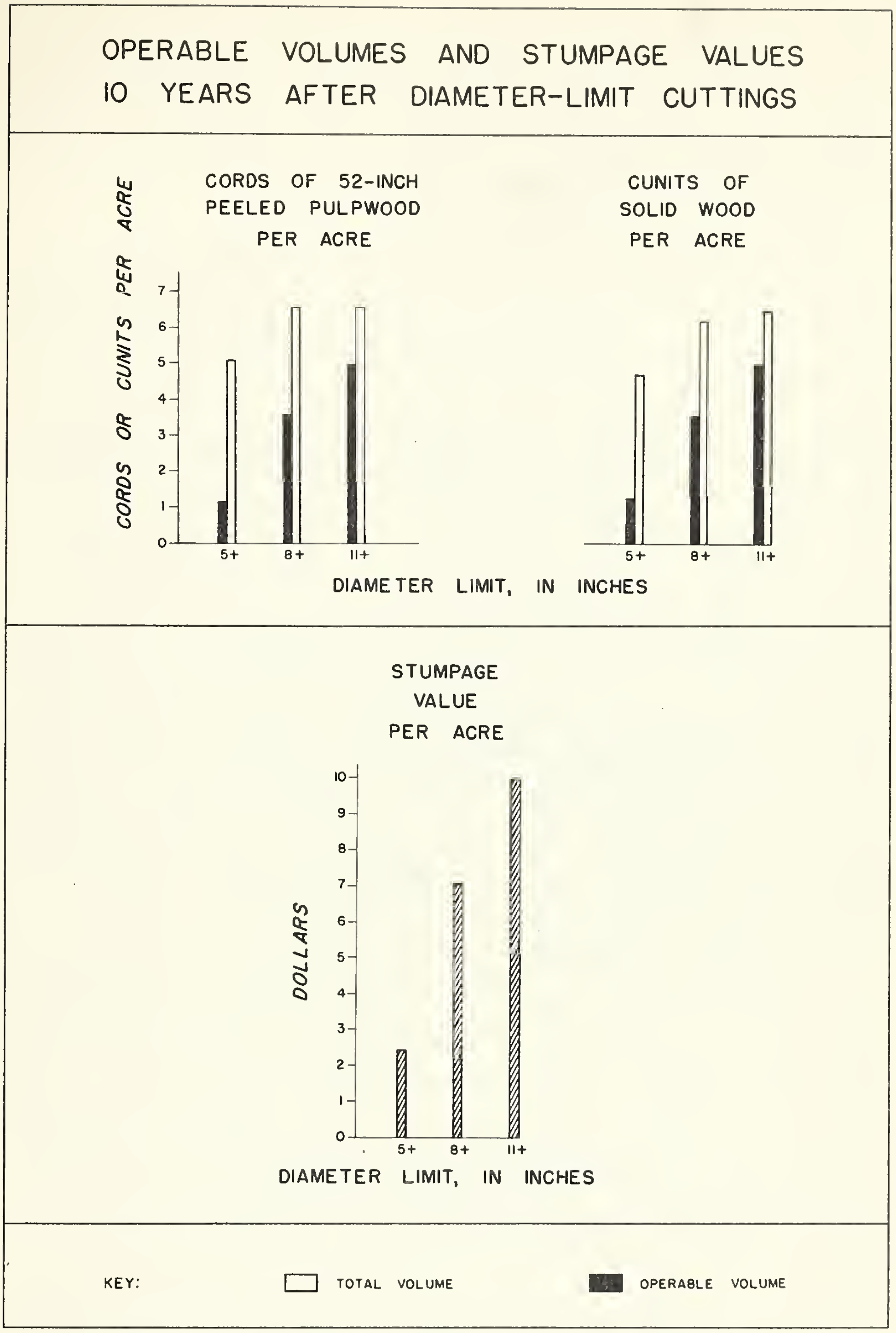

Figure 6.--Relationship of total 10-year volume growth per acre to operable cordwood volume, in stands where the different diameter limits were used. The stumpage values are based on $2 per cunit of peeled pulpwood.

pulpwood utilization call for a 4-inch top diameter inside bark. This limit is flexible. When a tree branches into small or crooked bolts, this top diameter is automatically increased to 5.6 inches or more. The top limit is often under 4 inches when an additional bolt of straight bole may be readily obtained.

This concept of minimum top diameter is often mistakenly applied to the size of trees profitable to operate. Of course the two ideas are not similar. Cutting all trees to as low a limit as 5 inches penalizes the woodcutter with reduced earnings. Reductions in the productivity of woods labor and increased costs per unit of wood cut are definitely not in the interest of the pulp company or the country as a whole. Such cutting methods are too drastic. The regrowth of stands cut to a 5-inch diameter is slower both in total volume of trees 5 inches d.b.h. and in operable volume of trees 8 inches d.b.h. and larger, than that of the other two diameter-limit cuttings tested.

A more prudent policy of handling second-growth Allegheny hardwoods for pulpwood production under the diameter-limit system of partial cuttings, would seem to be the use of a fairly high diameter limit, leaving an adequate number of vigorous subdominant trees for future growth. Such a harvest-cutting method will give better pulpwood growth and financial returns, will maintain more capital or growing stock for emergencies, and will require less acreage for the sustained production of the required amounts of wood than removal of all material to a 5-inch limit.

The cutting practice to be applied on any given forest property must be decided by the landowner. It may well vary from place to place, and it may change with the times. This right to handle private property as the landowner desires also carries with it certain responsibilities. Fortunately good forest practices are ordinarily also good economics, good labor relations, and good watershed protection. Such methods, used in second-growth stands, improve habitat for wildlife and provide the greatest possible protection from fire, storms, insects, disease, and drought damage. In general, cutting methods that result in the least drastic changes in the crown cover, maintain or improve the site quality, and result in a high rate of production of operable material on a short cutting cycle, are likely to prove the best from all standpoints in the long run.

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